CHAPTER 1

INTRODUCTION

1-1. Purpose and Scope. This manual provides guidance for the selection, design, installation, operation, and maintenance of cathodic protection systems (CPSs) used to supplement paint systems for corrosion control on civil works hydraulic structures. It also discusses possible solutions to some of the problems with CPSs that may be encountered at existing projects.

1-2. Applicability. This manual applies to all USACE Commands having civil works responsibilities.

1-3. References.

a. MIL-HDBK-1004/10, Electrical Engineering Cathodic Protection.

b. EM 1110-2-3400, Painting: New Construction and Maintenance.

c. ETL 1110-9-10, Cathodic Protection Systems Using Ceramic Anodes.

d. UFGS-09965A, Painting; Hydraulic Structures and Appurtenant Works.

e. UFGS-13113A, Cathodic Protection Systems (Impressed Current) for Lock Miter Gates.

f. TN ZMR-3-05, Components of Hydropower Projects Sensitive to Zebra Mussel Infestations.

g. NACE International Recommended Practice RP0169-2002, Control of External Corrosion on Underground or Submerged Metallic Piping Systems.

h. PROSPECT course handbook 009, 2003-01 et seq., Corrosion Control.

i. ERDC/CERL TR-01-73, Low-Maintenance Remotely Monitored Cathodic Protection Systems Requirements, Evaluation, and Implementation Guidance (Vicki L. Van Blaricum, William R. Norris, James B. Bushman, and Michael J. Szeliga), November 2001.

j. Calculations of Resistances to Ground (H. B. Dwight), Journ. AIEE Trans., vol 55, 1939, pp 1319 – 1328.

1-4. Background.

a. General. USACE uses CPSs in combination with protective coatings to mitigate corrosion of hydraulic structures immersed in fresh, brackish, or salt water. Protective coatings alone generally cannot offer complete corrosion protection because they usually contain some pinholes, scratches, and connected porosity, and over time these imperfections become increasingly permeable. As coatings degrade with time, these imperfections, commonly known as holidays, have a profound effect on overall coating integrity because of underfilm corrosion. CPSs, when used in conjunction with protective coatings, have been effective in controlling corrosion. CPSs consist of anodes that pass a protective current to the structure through the electrolyte environment. CPSs can be one of two types, sacrificial anode or impressed current anode. Hybrid CPSs installed on structures can include both types of anodes to provide protective current.

(1) Sacrificial CPSs. Sacrificial CPSs, also referred to frequently as galvanic CPSs, employ sacrificial anodes such as specific magnesium- or zinc-based alloys, which are anodic relative to the ferrous structure they are installed to protect. This inherent material property enables sacrificial anodes to function without an external power source, so they generally need very little maintenance after installation. However, by design, sacrificial anodes are consumed by corrosion during their service life and must be replaced periodically in order to ensure continuing protection of the structure. Therefore, these anodes should be installed in accessible locations on the structure. Sacrificial anode CPSs are generally recommended for use with a well coated structure that is expected to be well maintained or subjected to a minimum of damaging wear during its design life. (Note that in this EM the terms “sacrificial” and “galvanic” may be used interchangeably.)

(2) Impressed current CPSs. Impressed current systems employ anodes that are made of durable materials that resist electrochemical wear or dissolution. The impressed current is supplied by a power source such as a rectifier. All impressed current CPSs require periodic maintenance because they employ a power supply and are more complex than sacrificial systems. However, impressed current CPSs can be used effectively with bare or poorly coated structures because these systems include much flexibility in terms of the amount of protective current delivered and the ability to adjust it over time as conditions change.

b. Locations. Since 1950, USACE has used impressed current CPSs with graphite or high-silicon, chromium-bearing cast iron (HSCBCI) anodes. The first systems were installed on the Mississippi River near Rock Island, IL, on an experimental basis. Since then, CPSs have been used widely. About 22 CPSs were installed and are currently functioning on structures on the Tennessee-Tombigbee Waterway, the Alabama River, and the Black Warrior River in the Mobile District. CPSs have been used successfully on the Intercoastal Waterway on seven sector gates in the Jacksonville District and on miter gates in the New Orleans District. Impressed current systems have also been installed on three lock gates on the Columbia River in the Northwest.

Similarly, impressed current systems using both graphite and HSCBCI anodes were installed on lock gates on the Ohio River during the 1970s. However, ice and debris damage has made most of these systems inoperable. Since the early 1980s, a new type of ceramic-coated composite anode material has been used for various electrochemical processes, particularly in the electrolytic production of chlorine and cathodic protection systems, including off-shore, water tank, and groundbed applications. The mixed metal oxide ceramic-coated anodes consist of a conductive coating of iridium or ruthenium oxide ($IrO2$ and $RuO2$, respectively) applied by thermal decomposition onto specially prepared titanium substrates. The coatings are applied by spraying aqueous metallic salts onto the titanium substrates and heating to several hundred degrees Celsius. Multiple layers of coating material may be applied by the process to provide a maximum coating thickness of approximately 0.025 mm (1 mil). This type of impressed current CPS anode has been used at Pike Island and other locations with good results.

c. Inoperable impressed current systems. Most of the known inoperable impressed current systems utilized graphite anodes that were more than 20 years old. Only a few navigation structures have had systems that used ‘sausage string’ cast iron anodes provided with impact protection. Properly maintained and protected cast iron anode systems used in high-impact debris areas have provided good results. Graphite systems in low-impact debris areas have also shown good results.

d. Inoperable sacrificial anode systems. Zinc or magnesium sacrificial anodes provide some benefits, but they typically protect only smaller areas of bare metal and, consistent with their inherent material properties, they are consumed at higher rates than impressed current anodes. In order to be beneficial, sacrificial anodes must continue to apply current to the structure by design. Voltage testing must be conducted periodically and consumed anodes must be replaced promptly to keep the system operating in accordance with applicable criteria.

e. Solutions.

(1) Restoration of systems. Most existing inoperable CPSs at navigation structures can be restored. This approach is less expensive than installing complete new systems, and therefore should be considered first. When graphite anode strings are consumed or destroyed, they can be replaced with impact-protected cast iron sausage strings or ceramic-coated wire anodes. In many cases, anode strings can be replaced and systems can be repaired without dewatering a lock.

(2) New or replacement systems. Designers should use UFGS-13113A with this manual for new CPS installation or for complete system replacement when necessary.

f. Effective techniques. National Association of Corrosion Engineers (NACE) Recommended Practice RP0169-2002 specifies techniques for control of external corrosion on civil works hydraulic structures. It includes criteria for both coatings and cathodic protection, and should be used in conjunction with guidance in this manual and with painting design guidance in Engineer Manual EM 1110-2-3400. NACE RP0169-2002 should also be used as guidance unless noted otherwise, and designers should become familiar with it.

g. Resistivity policy. Cathodic protection should be provided on all submerged metallic structures. If, after performing a corrosion mitigation survey, an NACE-certified corrosion specialist or a professional engineer deems cathodic protection unnecessary due to a noncorrosive water, a statement to that effect should be prepared and sent to the district project manager as a part of the corrosion plan.